

NOVEL INDENO-FUSED PHOTOCHROMIC NAPHTHOPYRANS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to provisional
5 application Serial No. 60/258,973 filed on December 29, 2000.

DESCRIPTION OF THE INVENTION

The present invention relates to certain novel
naphthopyran compounds. More particularly, this invention
10 relates to novel indeno-fused photochromic naphthopyran
compounds and to compositions and articles containing such
novel naphthopyran compounds. When exposed to light radiation
containing ultraviolet rays, such as the ultraviolet radiation
in sunlight or the light of a mercury lamp, many photochromic
15 compounds exhibit a reversible change in color. When the
ultraviolet radiation is discontinued, such a photochromic
compound will return to its original color or colorless state.

Various classes of photochromic compounds have been
synthesized and suggested for use in applications in which a
20 sunlight-induced reversible color change or darkening is
desired. U.S. Patent 3,567,605 (Becker) describes a series of
pyran derivatives, including certain benzopyrans and
naphthopyrans. These compounds are described as derivatives
of chromene and are reported to undergo a color change, e.g.,
25 from colorless to yellow-orange, on irradiation by ultraviolet
light at temperatures below about -30°C. Irradiation of the
compounds with visible light or upon raising the temperature
to above about 0°C is reported to reverse the coloration to a
colorless state.

30 U.S. Patent 5,066,818 describes various 3,3-diaryl-
3H-naphtho[2,1-b]pyrans as having desirable photochromic
properties, i.e., high colorability and acceptable fade, for
ophthalmic and other applications. Also disclosed by way of
35 comparative example in the '818 patent are the isomeric 2,2-
diaryl-2H-naphtho[1,2-b]pyrans, which are reported to require
unacceptably long periods of time to fade after activation.

U.S. Patent 3,627,690 describes photochromic 2,2-di-
substituted-2H-naphtho[1,2-b]pyran compositions containing
minor amounts of either a base or weak-to-moderate strength
acid. The addition of either an acid or base to the
5 naphthopyran composition is reported to increase the fade rate
of the colored naphthopyrans, thereby making them useful in
eye protection applications such as sunglasses. It is
reported therein further that the fade rate of 2H-naphtho-
[1,2-b]pyrans without the aforementioned additives ranges from
10 several hours to many days to reach complete reversion.

Indenonaphthopyrans are known and have been
disclosed in U.S. Patents 5,645,767, 5,698,141, 5,723,072,
6,113,814 and 6,146,554 and International Patent Application
Publication No. WO 99/15518. In each of these disclosures,
15 the indeno group is in a reversed position as compared to the
indenonaphthopyrans of the present invention. Japan
Unexamined Patent Publication P2000-327675A discloses an
indenonaphthopyran in which the indeno group is substituted
with fluorenyl.

20 The present invention relates to a naphthopyran of
2H-naphtho[1,2-b]pyran structure characterized by having a
substituted or unsubstituted indeno group fused at the 2,3
positions of the group to the 1 side of the naphthopyran. The
compounds also have substituents at the 3 position of the
25 pyran ring. These compounds have unexpectedly been found to
demonstrate a bathochromic shift for the wavelength in the
visible spectrum at which the maximum absorption of the
activated (colored) form of the photochromic compound, i.e.,
the lambda max (Vis), occurs, thereby resulting in activated
30 colors ranging from yellow/brown to blue/gray. Due to the
bathochromic shift, compounds of the present invention
demonstrate different colors than similar compounds without an
unsubstituted or substituted indeno group fused at the 2,3
position of the group to the 1 side of the naphthopyran. In
35 addition, compounds of the present invention have demonstrated
a high molar absorptivity (or molar extinction coefficient) in

the UV, an acceptable fade rate without the addition of acids or bases, a high activated intensity, and a high coloration rate.

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DETAILED DESCRIPTION OF THE INVENTION

In recent years, photochromic plastic materials, particularly plastic materials for optical applications, have been the subject of considerable attention. In particular, photochromic ophthalmic plastic lenses have been investigated 10 because of the weight advantage they offer, vis-a-vis, glass lenses. Moreover, photochromic transparencies for vehicles, such as cars and airplanes, have been of interest because of the potential safety features that such transparencies offer.

Other than in the operating examples, or where 15 otherwise indicated, all values, such as those expressing wavelengths, quantities of ingredients, ranges or reaction conditions, used in this description and the accompanying claims are understood as modified in all instances by the term "about" which means close to or near.

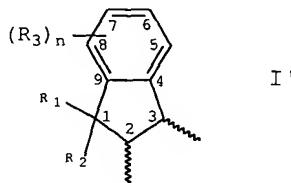
20 As used herein, the terms "halo" and "halogen" are defined to include chloro, fluoro, bromo and iodo and chlorine, fluorine, bromine and iodine, respectively. The term "aryl" is defined herein to include phenyl and naphthyl.

25 The disclosures of the patents and articles cited herein describing photochromic imbibition processes and compositions, procedures for making polymerizable and nonpolymerizable compounds of the present invention, complementary photochromic compounds, polymeric coatings and methods of applying such coatings, polymeric organic host 30 materials and polymerizates are incorporated herein, *in toto*, by reference.

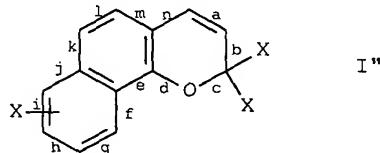
In accordance with the present invention, it has now been discovered that novel 2H-naphtho[1,2-b]pyran structures characterized by having a substituted or unsubstituted indeno 35 group fused at the 2,3 positions of the group to the 1 side of the naphthopyran and demonstrating activated colors ranging

from yellow/brown to blue/gray, an acceptable fade rate, high activated intensity and a high coloration rate may be prepared. These compounds may be described as indeno[3',2':3,4]naphtho[1,2-b]pyrans having substituents at 5 the 3 position of the pyran ring. Substituents may also be present at the number 5, 6, 7, 8, 9, 10, 11, 12, or 13 carbon atoms of the compounds. The indeno group may be represented by the following graphic formula I' in which numbers 1 through 9 represent the ring atoms of the indeno group.

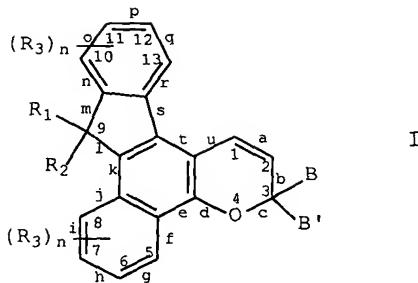
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A typical 2H-naphtho[1,2-b]pyran structure is represented by the following graphic formula I", in which the 15 letters a through n represent the sides and X represents potential substituents known in the art.



The compounds of the present invention may be 20 represented by the following graphic formula I in which the letters a through u represent the sides of the indenonaphthopyran rings, and the numbers represent the numbers of the ring atoms of the indenonaphthopyran.



The indenonaphthopyran of the present invention is a
5 naphthopyran compound of 2H-naphtho[1,2-b]pyran structure,
such as represented by graphic formula I", characterized by
having fused to the 1 side of the 2H-naphthopyran a group
represented by graphic formula I' at the 2,3 positions of
group I'. The group represented by graphic formula I' may be
10 unsubstituted such as when R₁ and R₂ are each hydrogen and
equals 0 or may be substituted with substituents known in the
art for use on photochromic compounds. Different embodiments
of the compounds of the present invention are contemplated
based on photochromic activity.

15 In graphic formulae I', R₁ and R₂ may each be
selected from the group consisting of:

(i) hydrogen, hydroxy, amino, mono- and di-
substituted amino, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₃-C₇
cycloalkyl, allyl, benzyl, mono-substituted benzyl, halogen
20 and the group, -C(O)W, wherein W is hydroxy, C₁-C₆ alkyl,
C₁-C₆ alkoxy, C₃-C₇ cycloalkyloxy, phenyl, mono-substituted
phenyl, phenoxy, amino, mono(C₁-C₆)alkylamino,
di(C₁-C₆)alkylamino, morpholino, piperidino or pyrrolidyl,
said amino substituents being selected from the group
25 consisting of C₁-C₆ alkyl, phenyl, benzyl and naphthyl, said
benzyl and phenyl substituents being C₁-C₆ alkyl, C₁-C₆
alkoxy, piperidino, morpholino, di(C₁-C₆)alkylamino or fluoro;

(ii) unsubstituted, mono- di- and tri-
substituted members selected from the group consisting of
phenyl, naphthyl, phenanthryl, pyrenyl, quinolyl, isoquinolyl,
benzofuranyl, thienyl, benzothienyl, dibenzofuranyl,
5 dibenzothienyl, carbazolyl, and indolyl, said group
substituents being selected from the group consisting of
halogen, C₁-C₆ alkyl, C₁-C₆ alkoxy, morpholino, piperidino,
pyrrolidino, amino, mono- and di-substituted amino, said amino
substituents being selected from the group consisting of C₁-C₆
10 alkyl, phenyl, benzyl and naphthyl;

(iii) monosubstituted phenyl, having a
substituent at the para position that is a linking group,
-(CH₂)_t- or -O-(CH₂)_t-, wherein t is the integer 1, 2, 3, 4, 5
or 6, connected to an aryl group, which is a member of another
15 photochromic naphthopyran;

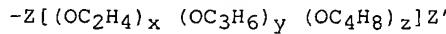
(iv) a group, -OR₅, wherein R₅ is C₁-C₆ alkyl,
C₁-C₆ acyl, phenyl(C₁-C₃)alkyl, mono(C₁-C₆)alkyl substituted
phenyl(C₁-C₃)alkyl, mono(C₁-C₆)alkoxy substituted
phenyl(C₁-C₃)alkyl, C₁-C₆ alkoxy(C₂-C₄)alkyl, C₃-C₇
20 cycloalkyl, mono(C₁-C₄)alkyl substituted C₃-C₇ cycloalkyl,
C₁-C₆ haloalkyl, allyl, benzoyl, monosubstituted benzoyl,
naphthoyl or monosubstituted naphthoyl, said benzoyl and
naphthoyl group substituents being C₁-C₆ alkyl or C₁-C₆
alkoxy; or R₅ is the group -CH(R₆)Q, wherein R₆ is hydrogen or
25 C₁-C₃ alkyl and Q is -CN, -CF₃, or -COOR₇, and R₇ is hydrogen
or C₁-C₃ alkyl; or R₅ is the group, -C(O)V, wherein V is
hydrogen, C₁-C₆ alkoxy, phenoxy, mono- or di-(C₁-C₆)alkyl
substituted phenoxy, mono- or di-(C₁-C₆)alkoxy substituted
phenoxy, an unsubstituted, mono- or di-substituted aryl group,
30 amino, mono(C₁-C₆)alkylamino, di(C₁-C₆)alkylamino,
phenylamino, mono- or di-(C₁-C₆)alkyl substituted phenylamino,
or mono- or di-(C₁-C₆)alkoxy substituted phenylamino, said
aryl group substituents being C₁-C₆ alkyl or C₁-C₆ alkoxy;

(v) a group, -CH(Q')₂, wherein Q' is -CN or
35 -COOR₈, wherein R₈ is hydrogen, C₁-C₆ alkyl,
phenyl(C₁-C₃)alkyl, mono(C₁-C₆)alkyl substituted

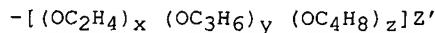
phenyl(C₁-C₃)alkyl, mono(C₁-C₆)alkoxy substituted phenyl(C₁-C₃)alkyl, or an unsubstituted, mono- or di-substituted aryl group, each of said aryl group substituents being C₁-C₆ alkyl or C₁-C₆ alkoxy;

5 (vi) a group, -CH(R₉)G, wherein R₉ is hydrogen, C₁-C₆ alkyl or an unsubstituted, mono- or di-substituted aryl group, and G is hydroxy, C₁-C₆ alkoxy, aryloxy, amino, mono(C₁-C₆)alkylamino, di(C₁-C₆)alkylamino, phenylamino, mono- or di-(C₁-C₆)alkyl substituted phenylamino, or mono- or di-(C₁-C₆)alkoxy substituted phenylamino, -COOR₈, -COR₁₀ or -CH₂OR₁₁, wherein R₁₀ is hydrogen, C₁-C₆ alkyl, an unsubstituted, mono- or di-substituted aryl group, amino, mono(C₁-C₆)alkylamino, di(C₁-C₆)alkylamino, phenylamino, mono- or di-(C₁-C₆)alkoxy substituted phenylamino, diphenylamino, mono- or di(C₁-C₆)alkyl substituted diphenylamino, mono- or di(C₁-C₆)alkoxy substituted diphenylamino, morpholino, or piperidino, wherein R₁₁ is hydrogen, -C(O)R₈, C₁-C₆ alkyl, C₁-C₃ alkoxy(C₁-C₆)alkyl, phenyl(C₁-C₃)alkyl, mono(C₁-C₆)alkoxy substituted phenyl(C₁-C₃)alkyl, or an unsubstituted, mono- or di-substituted aryl group, each of said aryl group substituents being C₁-C₆ alkyl or C₁-C₆ alkoxy; and

25 (vii) a group, T, represented by the formula:



or



wherein -Z is -C(O)- or -CH₂-, Z' is C₁-C₃ alkoxy or a polymerizable group i.e., any functional group capable of participating in a polymerization reaction.

30 Polymer forming methods in which the polymerizable compounds of the present invention may participate include radical polymerization, and such other polymerization processes as are described in *Ullmann's Encyclopedia of Industrial Chemistry*, "Polymerization Processes", Vol. 21A, pp 305 to 428. The 35 polymerizable groups may be selected from the group consisting of hydroxy, (meth)acryloxy, vinyl, isocyanate and epoxy, e.g.,

oxiranylmethyl. When there are 2 or more polymerizable groups on the naphthopyran, they may be the same or different, x, y and z are each a number between 0 and 50, and the sum of x, y and z is between 2 and 50; or

5 (viii) R₁ and R₂ may together form a substituted or unsubstituted spiro-carbocyclic ring containing 3 to 6 carbon atoms or a substituted or unsubstituted spiro-heterocyclic group containing 1 or 2 oxygen atoms and 3 to 6 carbon atoms including the spirocarbon atom, said spiro-
10 carbocyclic ring and spiro-heterocyclic group being annellated with 0, 1 or 2 benzene rings, said substituents being hydrogen or C₁-C₆ alkyl, provided that said spiro-carbocyclic ring is not fluoren-9-ylidene.

In one contemplated embodiment, R₁ and R₂ are each
15 selected from the group consisting of:

(i) hydrogen, hydroxy, C₁-C₆ alkyl, C₁-C₆ haloalkyl, di-substituted amino, C₃-C₇ cycloalkyl, benzyl, mono-substituted benzyl and the group, -C(O)W, wherein W is C₁-C₆ alkoxy, di(C₁-C₆)alkylamino, morpholino or piperidino,
20 said amino substituents being C₁-C₆ alkyl, said benzyl substituents being C₁-C₆ alkyl or C₁-C₆ alkoxy;

(ii) mono- and di and tri-substituted members selected from the group consisting of phenyl, naphthyl and dibenzofuranyl, said group substituents being selected from
25 the group consisting of C₁-C₆ alkyl, C₁-C₆ alkoxy, and di-substituted amino, said amino substituents being C₁-C₆ alkyl;

(iii) monosubstituted phenyl, having a substituent at the para position that is a linking group, -O-(CH₂)_t-, wherein t is the integer 3, 4 or 5 connected to an
30 aryl group, which is a member of another photochromic naphthopyran;

(iv) a group, -OR₅, wherein R₅ is C₁-C₆ alkyl, C₁-C₆ acyl, C₁-C₆ alkoxy (C₂-C₄) alkyl, benzoyl or monosubstituted benzoyl, said benzoyl substituents being C₁-C₆ alkyl or C₁-C₆ alkoxy; or R₅ is the group -CH(R₆)Q, wherein R₆ is hydrogen and Q is -COOR₇, and R₇ is C₁-C₃ alkyl; or R₅ is

the group, $-\text{C}(\text{O})\text{V}$, wherein V is $\text{C}_1\text{-C}_6$ alkoxy or $\text{di}(\text{C}_1\text{-C}_6)\text{alkyl}$ amino;

(v) a group, $-\text{CH}(\text{Q}')_2$, wherein Q' is $-\text{COOR}_8$, wherein R_8 is $\text{C}_1\text{-C}_6$ alkyl, or phenyl($\text{C}_1\text{-C}_3$)alkyl;

5 (vi) a group, $-\text{CH}(\text{R}_9)\text{G}$, wherein R_9 is $\text{C}_1\text{-C}_6$ alkyl, and G is $\text{C}_1\text{-C}_6$ alkoxy, $-\text{COOR}_8$ $-\text{COR}_{10}$, or $-\text{CH}_2\text{OR}_{11}$, wherein R_{10} is $\text{C}_1\text{-C}_6$ alkyl, di($\text{C}_1\text{-C}_6$)alkylamino, morpholino or piperidino; wherein R_{11} is $\text{C}_1\text{-C}_6$ alkyl or $\text{C}_1\text{-C}_3$ alkoxy($\text{C}_1\text{-C}_6$) alkyl, and

10 (vii) a group, T, represented by the formula:

$$-[(OC_2H_4)_x(OC_3H_6)_y(OC_4H_8)_z]Z'$$

wherein Z' is C₁-C₃ alkoxy or a polymerizable group, x, y and z are each a number between 0 and 50, and the sum of x, y and z is between 2 and 50; or

15 (viii) R_1 and R_2 may together form an oxo group or a substituted or unsubstituted spiro-heterocyclic group containing 1 or 2 oxygen atoms and 3 to 6 carbon atoms including the spirocarbon atom, said spiro-heterocyclic ring being annellated with 1 or 2 benzene rings, said substituent
20 being C_1-C_6 alkyl.

In another contemplated embodiment, R_1 and R_2 are each selected from the group consisting of:

(i) hydrogen, hydroxy, C_1-C_3 alkyl and the group, $-C(O)W$, wherein W is C_1-C_6 alkoxy,;

25 (ii) unsubstituted, and mono-substituted phenyl, said phenyl substituents being selected from the group consisting of C₁-C₆ alkoxy, and di-substituted amino, said amino substituents being C₁-C₃ alkyl;

(iii) monosubstituted phenyl, having a substituent at the para position that is a linking group, $-O-(CH_2)_t-$, wherein t is the integer 3, connected to an aryl group, which is a member of another photochromic naphthopyran:

(iv) a group, $-OR_5$, wherein R_5 is C_1-C_6 alkyl, C_1-C_6 alkoxy(C_2-C_4)alkyl, the group $-CH(R_6)Q$, wherein R_6 is hydrogen or C_1-C_3 alkyl and Q is $-COOR_7$, and R_7 is C_1-C_3 alkyl or R_5 is the group, $-C(O)V$, wherein V is C_1-C_6 alkoxy;

(v) a group, $-\text{CH}(\text{Q}')_2$, wherein Q' is $-\text{COOR}_8$, wherein R_8 is $\text{C}_1\text{-C}_6$ alkyl;

(vi) a group, $-\text{CH}(\text{R}_9)\text{G}$, wherein R_9 is $\text{C}_1\text{-C}_6$ alkyl, and G is $\text{C}_1\text{-C}_6$ alkoxy, $-\text{COOR}_8$, $-\text{COR}_{10}$ or $-\text{CH}_2\text{OR}_{11}$

5 wherein R_{10} and R_{11} are each $\text{C}_1\text{-C}_6$ alkyl; and

(vii) a group, T , represented by the formula:

$-\{(\text{OC}_2\text{H}_4)_x(\text{OC}_3\text{H}_6)_y(\text{OC}_4\text{H}_8)_z\}z'$

wherein z' is $\text{C}_1\text{-C}_3$ alkoxy or a polymerizable group, x , y and z are each a number between 0 and 50, and the 10 sum of x , y and z is between 2 and 50; or

(viii) R_1 and R_2 may together form a substituted or unsubstituted spiro-heterocyclic group containing 1 oxygen atom and 6 carbon atoms including the spirocarbon atom, said spiro-heterocyclic ring being 15 annellated with 2 benzene rings, said substituents being $\text{C}_1\text{-C}_3$ alkyl.

R_3 may be selected from the group of substituents known in the art for use on photochromic compounds. Each R_3 in graphic formula I may independently be selected from the 20 group consisting of hydrogen, $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ alkoxy, $\text{C}_3\text{-C}_7$ cycloalkyl, phenyl, benzyl, di($\text{C}_1\text{-C}_6$)alkylamino, dicyclohexylamino, diphenylamino, piperidyl, morpholinyl, pyridyl, halogen, a group, T , and the group $-\text{C}(\text{O})\text{W}$ and n is the integer 0, 1, or 2; or when n is at least 2, and the R_3 25 substituents are adjacent, the pair of substituents forms a substituted or unsubstituted fused carbocyclic or heterocyclic ring selected from the group consisting of benzo, pyridino, pyrazino, pyrimidino, furano, dihydrofuran, 1,3-dioxolo, 1,4-dioxolo, 1,3-dioxino, 1,4-dioxino, thiopheno, benzofuro, benzothieno, indolo, and indeno, the substituents of said 30 fused carbocyclic or heterocyclic ring being selected from the group consisting of halogen, $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ alkoxy, amino, mono- and di-substituted amino, said amino substituents being selected from the group consisting of $\text{C}_1\text{-C}_6$ alkyl, phenyl, 35 benzyl and naphthyl; said first R_3 ring being fused to the o,

p or q side and said second R₃ ring being fused to the g, h, or i side of the naphthopyran.

In one contemplated embodiment, each R₃ is selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ alkoxy, di(C₁-C₆)alkylamino, piperidyl, morpholinyl, pyrrolidyl, halogen, a group, T, or the group, -C(O)W and n is the integer 0, 1, or 2; or when n is 2, and the R₃ substituents are adjacent, a pair of substituents forms a substituted or unsubstituted fused carbocyclic or heterocyclic ring selected from the group consisting of benzo, dihydrofuran and benzofuro, the substituents of said fused carbocyclic or heterocyclic ring being selected from the group consisting of C₁-C₆ alkyl, C₁-C₆ alkoxy, and di-substituted amino, said amino substituents being C₁-C₆ alkyl; said R₃ ring being fused to the o, p or q sides of the naphthopyran.

In another contemplated embodiment, each R₃ is selected from the group consisting of hydrogen C₁-C₆ alkyl, C₁-C₆ alkoxy, morpholinyl, a group, T, and the group -C(O)W, and when m is 2 and the R₃ substituents are adjacent, the pair of substituents forms a substituted or unsubstituted fused carbocyclic or heterocyclic ring selected from the group consisting of benzo and benzofuro, the substituents of said fused carbocyclic or heterocyclic ring being C₁-C₆ alkoxy; said R₃ ring being fused to the p side of the naphthopyran.

In graphic formula I, R₁, R₂ and each R₃ are the same as described hereinbefore for graphic formula I'. In the definitions of R₁, R₂, R₃, B and B', like substituents have like meanings.

B and B' in graphic formula I may each be selected from the group of substituents known in the art for use on photochromic compounds. Specifically, B and B' may each be selected from the group consisting of:

- (i) mono-T-substituted phenyl
- (ii) an unsubstituted, mono-, di-, and tri-substituted aryl group;

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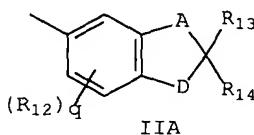
(iii) 9-julolidinyl and an unsubstituted, mono- or di-substituted heteroaromatic group selected from the group consisting of pyridyl, furanyl, benzofuran-2-yl, benzofuran-3-yl, thienyl, benzothien-2-yl, benzothien-3-yl, 5 dibenzofuranyl, dibenzothienyl, carbazoyl, benzopyridyl, indolinyl and fluorenlyl, each of said aryl and heteroaromatic substituents in (ii) and (iii) being selected from the group consisting of hydroxy, aryl, i.e., phenyl and naphthyl, mono(C_1 - C_6)alkoxyaryl, di(C_1 - C_6)alkoxyaryl, 10 mono(C_1 - C_6)alkylaryl, di(C_1 - C_6)alkylaryl, haloaryl, C_3 - C_7 cycloalkylaryl, C_3 - C_7 cycloalkyl, C_3 - C_7 cycloalkyloxy, C_3 - C_7 cycloalkyloxy(C_1 - C_6)alkyl, C_3 - C_7 cycloalkyloxy(C_1 - C_6)alkoxy, aryl(C_1 - C_6)alkyl, aryl(C_1 - C_6)alkoxy, aryloxy, aryloxy(C_1 - C_6)alkyl, aryloxy(C_1 - C_6)alkoxy, mono- and di- 15 (C_1 - C_6)alkylaryl(C_1 - C_6)alkyl, mono- and di- (C_1 - C_6)alkoxyaryl(C_1 - C_6)alkyl, mono- and di- (C_1 - C_6)alkylaryl(C_1 - C_6)alkoxy, mono- and di- (C_1 - C_6)alkoxyaryl(C_1 - C_6)alkoxy, amino, mono(C_1 - C_6)alkylamino, di(C_1 - C_6)alkylamino, diarylamino, aryl(C_1 - C_6 alkyl)amino, 20 piperazino, N-(C_1 - C_6)alkylpiperazino, N-arylpiperazino, aziridino, indolino, piperidino, morpholino, thiomorpholino, tetrahydroquinolino, tetrahydroisoquinolino, pyrryl, pyrrolidyl, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkoxy, mono(C_1 - C_6)alkoxy(C_1 - C_4)alkyl, acryloxy, methacryloxy and 25 halogen;

(iv) an unsubstituted or mono-substituted member selected from the group consisting of pyrazolyl, imidazolyl, pyrazolinyl, imidazolinyl, pyrrolinyl, phenothiazinyl, phenoxazinyl, phenazinyl and acridinyl, each 30 of said substituents being selected from the group consisting of C_1 - C_6 alkyl, C_1 - C_6 alkoxy, phenyl, and halogen;

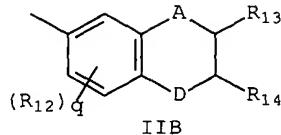
(v) monosubstituted phenyl, having a substituent at the para position that is a linking group, $-(CH_2)_t-$ or $-O-(CH_2)_t-$, wherein t is the integer 1, 2, 3, 4, 5 35 or 6, connected to an aryl group, which is a member of another photochromic naphthopyran;

(vi) a group represented by one of the following graphic formula IIA or IIB:

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IIA

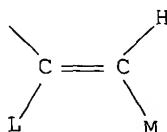


IIB

wherein A is methylene or oxygen and D is oxygen or substituted nitrogen, provided that when D is substituted 10 nitrogen, A is methylene, said nitrogen substituents being selected from the group consisting of hydrogen, C₁-C₆ alkyl, and C₂-C₆ acyl; each R₁₂ is C₁-C₆ alkyl, C₁-C₆ alkoxy, hydroxy, or halogen; R₁₃ and R₁₄ are each hydrogen or C₁-C₆ alkyl; and q is the integer 0, 1, or 2;

15 (vii) C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkoxy(C₁-C₄)alkyl, C₃-C₆ cycloalkyl, mono(C₁-C₆)alkoxy(C₃-C₆)cycloalkyl, mono(C₁-C₆)alkyl(C₃-C₆)-cycloalkyl, halo(C₃-C₆)cycloalkyl, and C₄-C₁₂ bicycloalkyl; and

20 (viii) a group represented by the following graphic formula IIC:



IIC

wherein L is hydrogen or C₁-C₄ alkyl and M is selected from 25 the unsubstituted, mono-, and di-substituted members of the group consisting of naphthyl, phenyl, furanyl, and thiienyl, each of said group substituents being C₁-C₄ alkyl, C₁-C₄ alkoxy, or halogen.

Alternatively, B and B' may together form fluoren-9-ylidene, mono-, or di-substituted fluoren-9-ylidene or form a 30 member selected from the group consisting of saturated C₃-C₁₂ spiro-monocyclic hydrocarbon rings, e.g., cyclopropylidene, cyclobutylidene, cyclopentylidene, cyclohexylidene,

cycloheptylidene, cyclooctylidene, cyclononylidene,
cyclodecylidene cycloundecylidene, cyclododecylidene;
saturated C₇-C₁₂ spiro-bicyclic hydrocarbon rings, e.g.,
bicyclo[2.2.1]heptylidene, i.e., norbornylidene, 1,7,7-
5 trimethyl bicyclo[2.2.1]heptylidene, i.e., bornylidene,
bicyclo[3.2.1]octylidene, bicyclo[3.3.1]nonan-9-ylidene,
bicyclo[4.3.2]undecane, and saturated C₇-C₁₂ spiro-tricyclic
hydrocarbon rings, e.g., tricyclo[2.2.1.0^{2,6}]heptylidene,
tricyclo[3.3.1.1^{3,7}]decylidene, i.e., adamantlylidene, and
10 tricyclo[5.3.1.1^{2,6}]dodecylidene, each of said fluoren-9-
ylidene substituents being selected from the group consisting
of C₁-C₄ alkyl, C₁-C₄ alkoxy, and halogen.

In one contemplated embodiment, B and B' are each selected from the group consisting of: (i) phenyl, mono-
15 substituted phenyl, and di-substituted phenyl, preferably substituted in the meta and/or para positions; (ii) the unsubstituted, mono- and di-substituted aromatic heterocyclic groups furanyl, benzofuran-2-yl, thieryl, benzothien-2-yl and dibenzofuranyl, each of said phenyl and aromatic heterocyclic
20 substituents being selected from the group consisting of hydroxy, amino, mono(C₁-C₃)alkylamino, di(C₁-C₃)alkylamino, piperidino, morpholino, pyrryl, C₁-C₃ alkyl, C₁-C₃ chloroalkyl, C₁-C₃ fluoroalkyl, C₁-C₃ alkoxy, mono(C₁-C₃)alkoxy(C₁-C₃)alkyl, fluoro and chloro; (iii) the
25 groups represented by the graphic formulae IIA and IIB, wherein A is methylene and D is oxygen, R₁₂ is C₁-C₃ alkyl or C₁-C₃ alkoxy, R₁₃ and R₁₄ are each hydrogen or C₁-C₄ alkyl; and q is the integer 0 or 1; (iv) C₁-C₄ alkyl; and (v) the group represented by the graphic formula IIC wherein L is
30 hydrogen or methyl and M is phenyl or mono-substituted phenyl, said phenyl substituent being selected from the group consisting of C₁-C₃ alkyl, C₁-C₃ alkoxy, and fluoro; or (vi) B and B' taken together form fluoren-9-ylidene, mono-substituted fluoren-9-ylidene or a member selected from the group
35 consisting of saturated C₃-C₈ spiro-monocyclic hydrocarbon rings, saturated C₇-C₁₀ spiro-bicyclic hydrocarbon rings, and

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saturated C₇-C₁₀ spiro-tricyclic hydrocarbon rings, said fluoren-9-ylidene substituent being selected from the group consisting of C₁-C₃ alkyl, C₁-C₃ alkoxy, fluoro and chloro.

In another contemplated embodiment, B and B' are

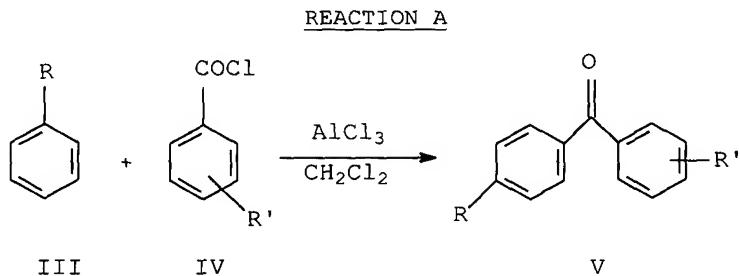
- 5 each selected from the group consisting of (i) phenyl, mono- and di-substituted phenyl, (ii) the unsubstituted, mono- and di-substituted aromatic heterocyclic groups furanyl, benzofuran-2-yl, thienyl, benzothien-2-yl and dibenzofuranyl, each of said phenyl and aromatic heterocyclic substituents
- 10 being selected from the group consisting of hydroxy, C₁-C₃ alkyl, C₁-C₃ alkoxy, piperidino and morpholino; and (iii) the group represented by graphic formula IIA, wherein A is methylene and D is oxygen, R₁₂ is C₁-C₃ alkyl or C₁-C₃ alkoxy, R₁₃ and R₁₄ are each hydrogen or C₁-C₃ alkyl, and q is the
- 15 integer 0 or 1; or (iv) B and B' taken together form fluoren-9-ylidene, adamantlylidene, bornylidene, norbornylidene, or bicyclo[3.3.1]nonan-9-ylidene.

Compounds represented by graphic formula I having certain of the substituents R₁-R₃, B and B' described hereinbefore, may be prepared by the following Reactions A through G. Methods for the preparation of compounds wherein R₁, R₂, B and/or B' is the polyalkoxylated group T are described in U. S. Patent 5,961,892. Methods for the preparation of compounds wherein R₁, R₂, B and/or B' is the polymerizable polyalkoxylated group T are described in U.S. Patent 6,113,814.

With reference to the following reactions, compounds represented by graphic formula V or VA are either purchased or prepared by Friedel-Crafts methods shown in Reaction A using an appropriately substituted or unsubstituted benzoyl chloride of graphic formula IV with a commercially available substituted or unsubstituted benzene compound of graphic formula III. See the publication Friedel-Crafts and Related Reactions, George A. Olah, Interscience Publishers, 1964, Vol. 3, Chapter XXXI (Aromatic Ketone Synthesis), and "Regioselective Friedel-Crafts Acylation of 1,2,3,4-

Tetrahydroquinoline and Related Nitrogen Heterocycles: Effect on NH Protective Groups and Ring Size" by Ishihara, Yugi et al, J. Chem. Soc., Perkin Trans. 1, pages 3401 to 3406, 1992.

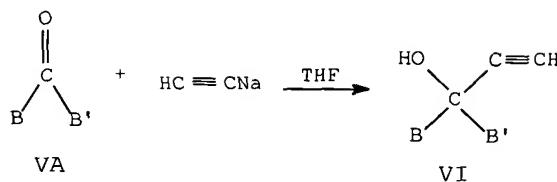
In Reaction A, the compounds represented by graphic formulae III and IV are dissolved in a solvent, such as carbon disulfide or methylene chloride, and reacted in the presence of a Lewis acid, such as aluminum chloride or tin tetrachloride, to form the corresponding substituted benzophenone represented by graphic formula V (VA in Reaction B). R and R' represent possible substituents, as described hereinbefore with respect to B and B' of graphic formula I.



15

In Reaction B, the substituted or unsubstituted ketone represented by graphic formula VA, in which B and B' may represent groups other than substituted or unsubstituted phenyl, as shown in graphic formula V, is reacted with sodium 20 acetylidyne in a suitable solvent, such as anhydrous tetrahydrofuran (THF), to form the corresponding propargyl alcohol represented by graphic formula VI. Propargyl alcohols having B or B' groups other than substituted and unsubstituted phenyl may be prepared from commercially available ketones or 25 ketones prepared via reaction of an acyl halide with a substituted or unsubstituted benzene, naphthalene or heteroaromatic compound, e.g., 9-julolidinyl. Propargyl alcohols having a B or B' group represented by graphic formula IIC may be prepared by the methods described in U.S. Patent 30 5,274,132, column 2, lines 40 to 68.

REACTION B



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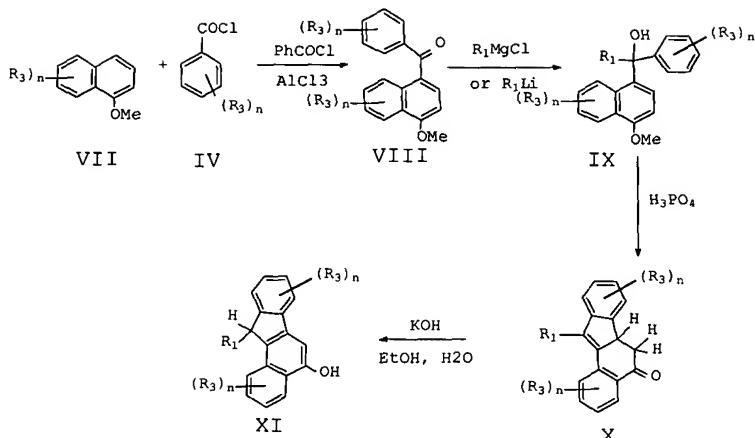
In Reaction C, a substituted or unsubstituted α -methoxy naphthalene represented by graphic formula VII is

10 reacted with a benzoyl chloride (IV) in the presence of anhydrous aluminum chloride to form a naphthophenone represented by graphic formula VIII. Compound VIII is reacted with an organometallic compound containing R₁ to give a carbinol compound represented by graphic formula IX. Compound

15 IX is heated with phosphoric acid to produce the ketone represented by graphic formula X. Compound X is aromatized by reaction with a base such as KOH in a water/ethanol mixture to produce the indeno-fused naphthol of graphic formula XI.

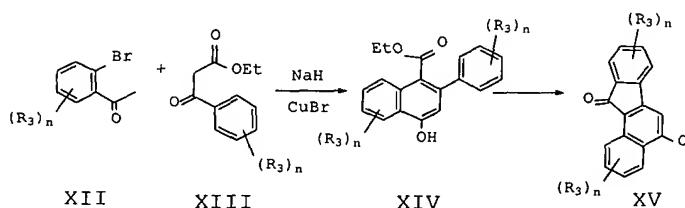
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REACTION C



In Reaction D, an ortho bromo acetophenone represented by graphic formula XII is reacted with ethyl, α -5 benzoylacetate represented by graphic formula XIII in the presence of sodium hydride and cuprous bromide to form a naphthol represented by graphic formula XIV. Naphthol XIV is then hydrolyzed with aqueous base followed by cyclization in strong acid such as phosphoric acid to produce the indeno-10 fused naphthol represented by graphic formula XV.

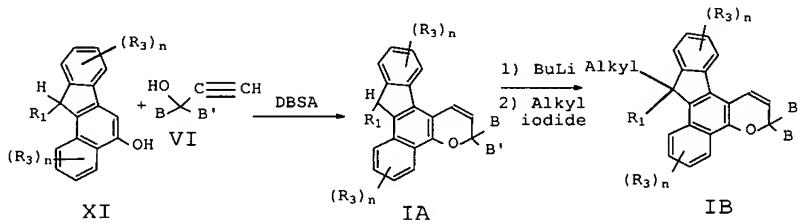
REACTION D



15 In Reaction E, the naphthol represented by graphic formula XI is coupled with a propragyl alcohol (VI) in the presence of a catalytic amount of a acid such as

p-dodecylbenzene sulfonic acid to form an indenonaphthopyran represented by graphic formula IA. Compound IA is reacted with a strong base such as butyl lithium or KOH and followed by reaction with alkyl halide to produce the 5 indenonaphthopyran represented by graphic formula IB.

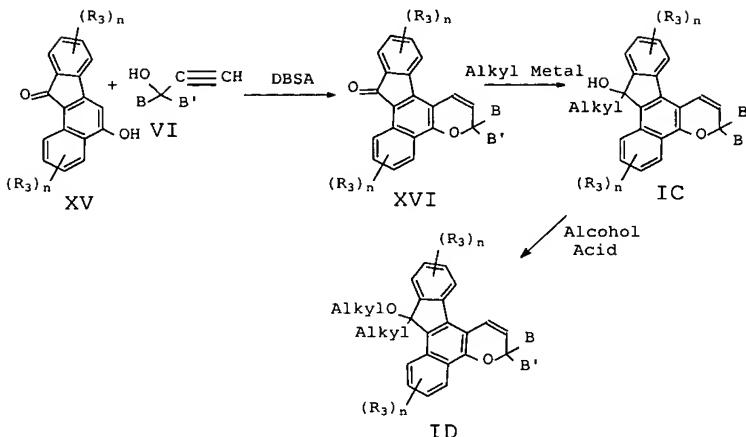
REACTION E



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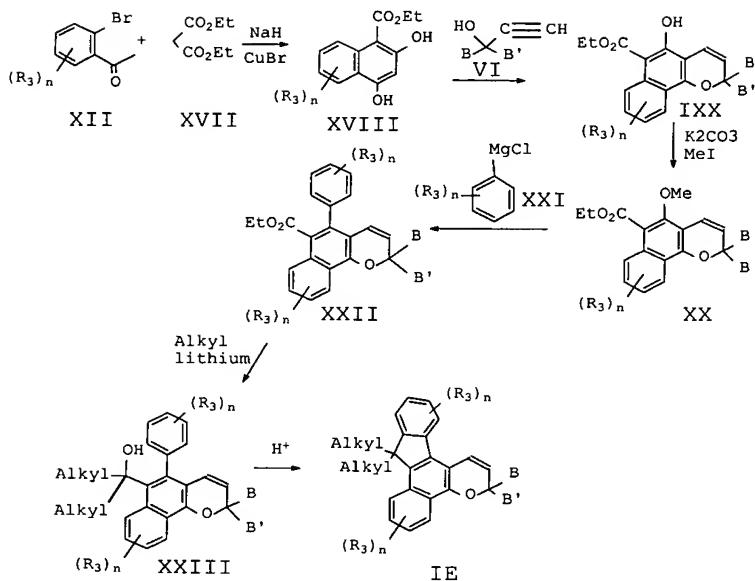
In Reaction F, the naphthol represented by graphic formula XV is coupled with propargyl alcohol to give the indenonaphthopyran represented by graphic formula XVI. Compound XVI is reacted with an organo metallic compound to 15 produce the indenonaphthopyran of graphic formula IC. The hydroxy group on compound IC is alkylated with alcohol to form an ether substituent on the indenonaphthopyran of graphic formula ID.

REACTION F



In Reaction G, the ortho bromoacetophenone represented by graphic formula XII is reacted with diethyl malonate represented by graphic formula XVII in the presence of sodium hydride and cuprous bromide to form a dihydroxy naphthalene represented by graphic formula XVIII. Compound XVIII is coupled with a propargyl alcohol (VI) to produce the naphthopyran represented by graphic formula IXX. Compound IXX is methylated with methyl iodide in the presence of potassium carbonate to form the naphthopyran represented by graphic formula XX. The reaction of the aryl Grignard reagent represented by graphic formula XXI with compound XX produces the naphthopyran represented by graphic formula XXII. Compound XXII is reacted with alkyl lithium to produce a carbinol derivative represented by graphic formula XXIII. Cyclization of Compound XXIII with acid forms the desired indenonaphthopyran represented by graphic formula IE.

REACTION G



Compounds represented by graphic formula I may be used in those applications in which organic photochromic substances may be employed, such as optical lenses, e.g., vision correcting ophthalmic lenses, contact lenses and plano lenses, face shields, goggles, visors, camera lenses, windows, automotive windshields, aircraft and automotive transparencies, e.g., T-roofs, sidelights and backlights, plastic films and sheets, textiles and coatings, e.g., coating compositions. As used herein, coating compositions are defined herein to include polymeric coating compositions prepared from materials such as polyurethanes, epoxy resins and other resins used to produce synthetic polymers; paints, i.e., a pigmented liquid or paste used for the decoration, protection and/or the identification of a substrate; and inks, i.e., a pigmented liquid or paste used for writing and printing on substrates. Potential substrates for coating compositions containing the compounds of the present invention

include paper, glass, ceramics, wood, masonry, textiles, metals and polymeric organic materials.

Coating compositions may be used to produce coatings on optical elements, verification marks on security documents, 5 e.g., documents such as banknotes, passport and drivers' licenses, for which authentication or verification of authenticity may be desired. The indenonaphthopyrans represented by graphic formula I exhibit color changes from colorless to colors ranging from yellow/brown to blue/gray.

10 Examples of indenonaphthopyran compounds within the scope of the invention are the following:

- (a) 3,3,9-triphenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (b) 3,3-di(4-methoxyphenyl)-9-phenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (c) 3-(4-methoxyphenyl)-3,9-diphenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (d) 3-(4-morpholinophenyl)-3,9-diphenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (e) 3,3-di(4-methoxyphenyl)-9-(3-methoxyphenyl)-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (f) 3-(4-methoxyphenyl)-3-phenyl-9-(3-methoxyphenyl)-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (g) 3-(4-methoxyphenyl)-3-phenyl-9-methyl-11-methoxy-9-(3-methoxyphenyl)-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (h) 3,3-di(4-methoxyphenyl)-9-methyl-11-methoxy-9-(3-methoxyphenyl)-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (i) 3,3-di(4-methoxyphenyl)-9-methyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (j) 3,3-di(4-methoxyphenyl)-9,9-dimethyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;
- (k) 3-(4-methoxyphenyl)-3-phenyl-9,9-dimethyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;

(l) 3,3-di(4-methoxyphenyl)-9,9-dimethyl-7,11-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;

(m) 3-(4-methoxyphenyl)-3-phenyl-9,9-dimethyl-7,11-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;

5 (n) 3-(4-morpholinophenyl)-3-phenyl-9,9-dimethyl-7,11-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;

(o) 3,3-di(4-methoxyphenyl)-9-methyl-11,13-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;

(p) 3-(4-methoxyphenyl)-3-phenyl-9-methyl-11,13-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran;

10 (q) 3-(4-methoxyphenyl)-3-phenyl-9,9-dimethyl-3H-9H-benzo[4",5"]indeno[3',2':3,4]naphtho[1,2-b]pyran; and

(r) 3,3-di(4-methoxyphenyl-9,9-dimethyl-11-fluoro-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

15 It is contemplated that the photochromic indenonaphthopyrans of the present invention may each be used alone or in combination with other indenonaphthopyrans of the present invention. Alternatively, the photochromic indenonaphthopyrans of the present invention may be used in combination with one or more other appropriate complementary organic photochromic materials, i.e., organic photochromic compounds having at least one activated absorption maxima within the range of between 400 and 700 nanometers, or substances containing the same. The photochromic compounds

20 may be incorporated, e.g., dissolved or dispersed, in a polymeric organic host material used to prepare photochromic articles which color when activated to an appropriate hue. The complementary organic photochromic materials may include indenonaphthopyrans, naphthopyrans, benzopyrans, phenanthropyrans, spiro(benzindoline)naphthopyrans, spiro(indoline)benzopyrans, spiro(indoline)naphthopyrans, spiro(indoline)quinopyrans, spiro(indoline)pyrans, spiro(indoline)naphthoxazines, spiro(indoline)pyridobenzoxazines,

25 spiro(benzindoline)pyridobenzoxazines, spiro(benzindoline)naphthoxazines,

spiro(indoline)benzoxazines, organo-metaldithizonates, e.g. mercury dithizonates, fulgides, fulgimides and mixtures of such photochromic compounds. Such photochromic compounds are described in U.S. Patents 5,645,767 and 6,153,126.

5 The photochromic compounds of the present invention may be associated with a polymeric organic host material or other substrate by various means. They may be incorporated, i.e., dissolved and/or dispersed, into the host material, polymerized with other components of the host material, and/or 10 incorporated into a coating applied to a substrate, e.g., a polymeric coating applied to one surface of the polymeric organic host material.

Each of the photochromic substances described herein may be used in amounts (or in a ratio) such that an organic 15 host material or substrate to which the photochromic compounds or mixture of compounds is associated, exhibits a desired resultant color, e.g., a substantially neutral color when activated with unfiltered sunlight, i.e., as near a neutral color as possible given the colors of the activated 20 photochromic compounds. Neutral gray and neutral brown colors are preferred. Further discussion of neutral colors and ways to describe colors may be found in U.S. Patent 5,645,767 column 12, line 66 to column 13, line 19.

The amount of the photochromic indenonaphthopyrans 25 to be applied to or incorporated into a coating composition or host material is not critical provided that a sufficient amount is used to produce a photochromic effect discernible to the naked eye upon activation. Generally such amount can be described as a photochromic amount. The particular amount 30 used depends often upon the intensity of color desired upon irradiation thereof and upon the method used to incorporate or apply the photochromic compounds. Typically, the more photochromic compound applied or incorporated, the greater is the color intensity up to a certain limit.

35 The relative amounts of the aforesaid photochromic compounds used will vary and depend in part upon the relative

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intensities of the color of the activated species of such compounds, the ultimate color desired and the method of application to the host material or substrate. Generally, the amount of total photochromic compound incorporated into or
5 applied to a photochromic optical host material may range from 0.05 to 2.0, e.g., from 0.2 to 1.0, milligrams per square centimeter of surface to which the photochromic compound is incorporated or applied. The amount of photochromic material incorporated into a coating composition may range from 0.1 to
10 40 weight percent based on the weight of the liquid coating composition.

The photochromic indenonaphthopyrans of the present invention may be associated with the host material by various methods described in the art. See, for example, column 13,
15 lines 40 to 58 of U.S. Patent 5,645,767. Aqueous or organic solutions or dispersions of the photochromic compounds may be used to incorporate the photochromic compounds into a polymeric organic host material or other materials such as textiles and coating compositions. Coating compositions may
20 be applied to the substrate using a coating process such as that described in U.S. Patents 3,971,872, 6,025,026 and 6,150,430.

Application of the polymeric coating may be by any of the methods used in coating technology such as, for
25 example, spray coating, spin coating, spread coating, curtain coating, dip coating, casting or roll-coating and methods used in preparing overlays, such as the method of the type described in U.S. Patent 4,873,029. The application method selected also depends on the thickness of the cured coating.
30 Coatings having a thickness ranging from 1 to 50 microns may be applied by conventional methods used in coating technology. Coatings of a thickness greater than 50 microns may require molding methods typically used for overlays.

The polymeric coating composition includes
35 compositions resulting in thermoplastic or thermosetting coatings, which are described in the Kirk-Othmer Encyclopedia

of Chemical Technology, Fourth Edition, Volume 6, pages 669 to 760. The coating may comprise at least one polymer selected from the group consisting of polyurethanes, melamine resins, polyvinyl alcohol, polyacrylates, polymethacrylates, polyamide 5 resins and epoxy resins. Such polymer-forming coating compositions are described in U.S. Patent 4,425,403.

The host material will usually be transparent, but may be translucent or even opaque. The host material need only be pervious to that portion of the electromagnetic 10 spectrum, which activates the photochromic substance, i.e., that wavelength of ultraviolet (UV) light that produces the open or colored form of the substance and that portion of the visible spectrum that includes the absorption maximum wavelength of the substance in its UV activated form, i.e., 15 the open form. Preferably, the host color should not be such that it masks the color of the activated form of the photochromic compounds, i.e., so the change in color is readily apparent to the observer. Compatible tints may be applied to the host material as described in U.S. Patent 20 5,645,767 in column 13, line 59 to column 14, line 3.

Most preferably, the polymeric organic host material is a solid transparent or optically clear material, e.g., materials suitable for optical applications, such as plano, ophthalmic and contact lenses, windows, automotive 25 transparencies, e.g., windshields, aircraft transparencies, plastic sheeting, polymeric films, etc.

Examples of polymeric organic host materials which may be used with the photochromic compounds described herein include: polymers, i.e., homopolymers and copolymers, of the 30 bis(allyl carbonate) monomers, diethylene glycol dimethacrylate monomers, diisopropenyl benzene monomers, ethoxylated bisphenol A dimethacrylate monomers, ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, ethoxylated phenol bismethacrylate 35 monomers, alkoxyLATED polyhydric alcohol acrylate monomers, such as ethoxylated trimethylol propane triacrylate monomers,

urethane acrylate monomers, such as those described in U.S. Patent 5,373,033, and vinylbenzene monomers, such as those described in U.S. Patent 5,475,074 and styrene; polymers, i.e., homopolymers and copolymers, mono- or polyfunctional, 5 e.g., di- or multi-functional, acrylate and/or methacrylate monomers, poly(C₁-C₁₂ alkyl methacrylates), such as poly(methyl methacrylate), poly(oxyalkylene)dimethacrylate, poly(alkoxylated phenol methacrylates), cellulose acetate, cellulose triacetate, cellulose acetate propionate, cellulose 10 acetate butyrate, poly(vinyl acetate), poly(vinyl alcohol), poly(vinyl chloride), poly(vinylidene chloride), polyurethanes, polythiourethanes, thermoplastic polycarbonates, polyesters, poly(ethylene terephthalate), polystyrene, poly(alpha methylstyrene), copoly(styrene-methyl 15 methacrylate), copoly(styrene-acrylonitrile), polyvinylbutyral and polymers, i.e., homopolymers and copolymers, of diallylidene pentaerythritol, particularly copolymers with polyol (allyl carbonate) monomers, e.g., diethylene glycol bis(allyl carbonate), and acrylate monomers, e.g., ethyl 20 acrylate, butyl acrylate. Further examples of polymeric organic host materials are disclosed in the U.S. Patent 5,753,146, column 8, line 62 to column 10, line 34.

Transparent copolymers and blends of transparent polymers are also suitable as host materials. Preferably, the 25 host material or substrate for the photochromic polymeric coating composition is an optically clear polymerized organic material prepared from a thermoplastic polycarbonate resin, such as the carbonate-linked resin derived from bisphenol A and phosgene, which is sold under the trademark, LEXAN; a 30 polyester, such as the material sold under the trademark, MYLAR; a poly(methyl methacrylate), such as the material sold under the trademark, PLEXIGLAS; polymerizes of a polyol(allyl carbonate) monomer, especially diethylene glycol bis(allyl carbonate), which monomer is sold under the 35 trademark CR-39, and polymerizes of copolymers of a polyol (allyl carbonate), e.g., diethylene glycol bis(allyl

carbonate), with other copolymerizable monomeric materials, such as copolymers with vinyl acetate, e.g., copolymers of from 80-90 percent diethylene glycol bis(allyl carbonate) and 10-20 percent vinyl acetate, particularly 80-85 percent of the 5 bis(allyl carbonate) and 15-20 percent vinyl acetate, and copolymers with a polyurethane having terminal diacrylate functionality, as described in U.S. Patents 4,360,653 and 4,994,208; and copolymers with aliphatic urethanes, the terminal portion of which contain allyl or acrylyl functional 10 groups, as described in U.S. Patent 5,200,483; poly(vinyl acetate), polyvinylbutyral, polyurethane, polythiourethanes, polymers of members of the group consisting of diethylene glycol dimethacrylate monomers, diisopropenyl benzene monomers, ethoxylated bisphenol A dimethacrylate monomers, 15 ethylene glycol bismethacrylate monomers, poly(ethylene glycol) bismethacrylate monomers, ethoxylated phenol bismethacrylate monomers and ethoxylated trimethylol propane triacrylate monomers; cellulose acetate, cellulose propionate, cellulose butyrate, cellulose acetate butyrate, polystyrene 20 and copolymers of styrene with methyl methacrylate, vinyl acetate and acrylonitrile.

More particularly contemplated is use of the photochromic indenonaphthopyrans of the present invention with optical organic resin monomers used to produce optically clear 25 coatings and polymerizates, i.e., materials suitable for optical applications, such as for example plano and ophthalmic lenses, windows, and automotive transparencies. Such optically clear polymerizates may have a refractive index that may range from 1.48 to 1.75, e.g., from 1.495 to 1.66.

30 Specifically contemplated are polymerizates of optical resins sold by PPG Industries, Inc. under the CR-designation, e.g., CR-307, CR-407 and CR-607, and polymerizates prepared for use as hard or soft contact lenses. Methods for producing both types of contact lenses are 35 disclosed in U.S. Patent 5,166,345, column 11, line 52, to column 12, line 52. Additional polymerizates contemplated for

use with the photochromic naphthopyrans of the present invention are polymerizates used to form soft contact lenses with high moisture content described in U.S. Patent 5,965,630 and extended wear contact lenses described in U.S. Patent 5 5,965,631.

The present invention is more particularly described in the following examples, which are intended as illustrative only, since numerous modifications and variations therein will be apparent to those skilled in the art.

10

EXAMPLE 1

STEP 1

1-Methoxynaphthalene (100 grams), 108 grams of benzoyl chloride and 600 milliliters (mL) of methylene 15 chloride were mixed in a dry round bottom flask and stirred at 3-5°C. Anhydrous aluminum chloride (100 grams) was slowly added to the reaction mixture and stirred for 2 hours. The reaction mixture was poured into a 2 liter 10% hydrochloric acid/ice mixture and stirred for a half hour. The organic 20 layer was separated, washed with water and then by 5 weight percent NaOH aqueous solution and again washed with water. The organic layer was dried over magnesium sulfate and filtered. The filtrate was concentrated and crystallized from hexane to give 160 grams of a solid product. The Nuclear Magnetic 25 Resonance (NMR) analysis showed the product to have a structure consistent with phenyl 1-(4-methoxynaphthyl) methanone.

STEP 2

Phenyl 1-(4-methoxynaphthyl) methanone (3.5 grams, 30 13.3 millimoles) was dissolved in 60 mL of anhydrous tetrahydrofuran under the atmosphere of nitrogen in a reaction flask, and the reaction mixture was cooled to -5 °C. Excess phenyl lithium (1.8 M solution, 14.3 mL) was added dropwise, with stirring, and the reaction mixture was stirred overnight. 35 The reaction mixture was quenched with water and acidified to

a pH of 7 with 2 Normal (N) aqueous hydrochloric acid (HCl). The organic phase was separated, the solvents were removed to quantitatively yield a yellow solid. Mass Spectroscopy and Proton NMR analysis showed the product to have a structure 5 consistent with diphenyl-(1-(4-methoxy)naphthyl)methanol.

STEP 3

Diphenyl-(1-(4-methoxy)-naphthyl)methanol (2.39 grams, 7.03 millimole) was added, with stirring, to a reaction flask containing preboiled o-phosphoric acid (50 mL). The 10 reaction mixture was heated to 100°C over a period of 50 minutes. The reaction mixture was poured onto ice. The resulting organic precipitate was separated by filtration and washed with water. The aqueous phase was extracted with ethyl acetate. The ethyl acetate phase was separated and dried over 15 anhydrous magnesium sulfate. The solvent was removed under reduced pressure. The organic solids were combined to yield a yellowish solid that was taken on to the next step without further purification. The Mass spectroscopy, Proton and Carbon-13 NMR analysis showed the product to have a structure 20 consistent with 7-phenyl-1,11b-dihydrobenzyl(a)fluoren-2-one.

STEP 4

The yellow solid from Step 3 was added to a reaction flask containing toluene (100 mL). A solution of potassium hydroxide (1.75 grams) in 95% ethanol (50 mL) was added, and 25 the reaction mixture was boiled for an hour. The organic solvents were removed under reduced pressure, ethyl acetate was added, and the mixture was washed with 2 N aqueous HCl to quench the residual base. The organic phase was separated and dried over anhydrous sodium sulfate, the solvent was removed 30 under reduced pressure, and the residual oil was crystallized from hexanes to yields 1.85 grams of a brown powder. NMR analysis showed the product to have a structure consistent with 7-phenyl-benzo(a)fluoren-2-ol.

STEP 5

7-Phenyl-benzo(a)fluoren-2-ol from Step 4 (0.4 gram) was added to a reaction flask containing 40 mL of chloroform. A catalytic amount of p-dodecylbenzene sulfonic acid (approximately 20 milligrams) was added, followed by 1,1-diphenyl-2-propyn-1-ol (0.21 gram) and the reaction mixture was stirred at ambient temperature for 24 hours. The solvent was removed under reduced pressure. The reaction mixture was separated by column chromatography using as the eluant a 1:2 mixture of dichloromethane:hexanes. The top fraction was collected. The solvent was removed by evaporation and the residue was triturated with methanol to yield 0.21 gram of a light pink solid. The Proton and Carbon-13 NMR and MS analysis showed the product to have a structure consistent with 3,3,9-triphenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 2

The procedure of Example 1 was followed except that in Step 5, 1,1-bis(4-methoxyphenyl)-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol to produce the desired product. NMR analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9-phenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

25

Example 3

The procedure of Example 1 was followed except that in Step 5, 1-phenyl,1-(4-methoxyphenyl)-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol and a 1:9 mixture of ethyl acetate/hexanes was used as eluant to produce the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-methoxyphenyl)-3,9-diphenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 4

The procedure of Example 1 was followed except that in Step 5, 1-phenyl,1-(4-morpholinophenyl)-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol and a 1:9 mixture 5 of ethyl acetate/hexanes was used as eluant to produce the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-morpholinophenyl)-3,9-diphenyl-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

10

Example 5

The procedure of Example 1 was followed except that in Step 1, 3-methoxybenzoyl chloride was used in place of benzoyl chloride and in Step 2, 3-methoxyphenyl magnesium bromide was used in place of phenyl lithium and in Step 5, 15 1,1-bis(4-methoxyphenyl)-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol and a 5:4:1 mixture of hexanes/dichloromethane/ethyl acetate/ was used as eluant to produce the desired product. NMR analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9-20 (3-methoxyphenyl)-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 6

The procedure of Example 5 was followed except that 25 in Step 5, 1-phenyl,1-(4-methoxyphenyl)-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol and a 5:4:1 mixture of hexanes/dichloromethane/ethyl acetate/ was used as eluant to produce the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-methoxyphenyl)-3-30 phenyl-9-(3-methoxyphenyl)-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 7

The product of Example 6, 3-(4-methoxyphenyl)-3-35 phenyl-9-(3-methoxyphenyl)-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran (0.53 gram) was added to a reaction flask

containing 20 mL of anhydrous tetrahydrofuran. The reaction mixture was cooled to -78 °C. n-Butyl lithium (2.5 M in hexanes, 1.6 mL) was added dropwise with stirring, under an atmosphere of nitrogen. An immediate color change from light 5 brown to dark brown was observed. The reaction mixture was stirred for 30 minutes, at which time methyl iodide (0.8 mL, 12.8 mmol) was added dropwise with stirring. The reaction mixture was stirred for 24 hours at ambient temperature. The solvents were removed under reduced pressure. The residue was 10 treated with 20 mL of water. The organic solids were combined and separated by column chromatography using as the eluant a 15:4:1 mixture of hexanes/dichloromethane/ethyl acetate to yield 0.4 gram of a yellow solid product. The Proton and Carbon-13 NMR and MS analysis showed the product to have a 15 structure consistent with 3-(4-methoxyphenyl)-3-phenyl-9-methyl-11-methoxy-9-(3-methoxyphenyl)-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 8

20 The procedure of Example 7 was followed except that 3,3-di(4-methoxyphenyl)-9-(3-methoxyphenyl)-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran was used in place of 3-(4-methoxyphenyl)-3-phenyl-9-(3-methoxyphenyl)-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran to produce the desired 25 product. The Proton and Carbon-13 NMR and MS analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9-methyl-11-methoxy-9-(3-methoxyphenyl)-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

30 Example 9

The procedure of Example 1 was followed except that in Step 1, 3-methoxybenzoyl chloride was used in place of benzoyl chloride and in Step 2, methyl magnesium chloride was used in place of phenyl lithium and in Step 5, 1,1-bis(4-methoxyphenyl)-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol to produce the desired product. NMR 35

analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9-methyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

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Example 10

The procedure of Example 7 was followed except that 3,3-di(4-methoxyphenyl)-9-methyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran was used in place of 3-(4-methoxyphenyl)-3-phenyl-9-(3-methoxyphenyl)-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran to produce the desired product. The Proton and Carbon-13 NMR and MS analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9,9-dimethyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

15

Example 11

The procedure of Example 10 was followed except that in Step 5, 1-(4-methoxyphenyl)-1-phenyl-2-propyn-1-ol was used in place of 1,1-diphenyl-2-propyn-1-ol to produce the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-methoxyphenyl)-3-phenyl-9,9-dimethyl-11-methoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

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Example 12

The procedure of Example 11 was followed except that in Step 1, 3-methoxybenzoyl chloride was used in place of benzoyl chloride and 1,6-dimethoxynaphthalene was used in place of 1-methoxynaphthalene to produce the desired product. NMR analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9,9-dimethyl-7,11-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

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Example 13

The procedure of Example 12 was followed except that in Step 5, 1-(4-methoxyphenyl)-1-phenyl-2-propyn-1-ol was used in place of 1,1-di(4-methoxyphenyl)-2-propyn-1-ol to produce 5 the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-methoxyphenyl)-3-phenyl-9,9-dimethyl-7,11-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 14

10 The procedure of Example 12 was followed except that in Step 5, 1-(4-morpholinophenyl)-1-phenyl-2-propyn-1-ol was used in place of 1,1-di(4-methoxyphenyl)-2-propyn-1-ol to produce the desired product. NMR analysis showed the product 15 to have a structure consistent with 3-(4-morpholinophenyl)-3-phenyl-9,9-dimethyl-7,11-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 15

20 The procedure of Example 9 was followed except that in Step 1, 3,5-dimethoxybenzoyl chloride was used in place of benzoyl chloride to produce the desired product. NMR analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl)-9-methyl-11,13-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 16

30 The procedure of Example 15 was followed except that in Step 5, 1-(4-methoxyphenyl)-1-phenyl-2-propyn-1-ol was used in place of 1,1-di(4-methoxyphenyl)-2-propyn-1-ol to produce the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-methoxyphenyl)-3-phenyl-9-methyl-11,13-dimethoxy-3H-9H-indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 17

The procedure of Example 11 was followed except that in Step 1, 1-naphthoyl chloride was used in place of 3-methoxybenzoyl chloride to produce the desired product. NMR analysis showed the product to have a structure consistent with 3-(4-methoxyphenyl)-3-phenyl-9,9-dimethyl-3H-9H-benzo[4",5"]indeno[3',2':3,4]naphtho[1,2-b]pyran.

Example 18

10 The procedure of Example 10 was followed except that in Step 1, 3-fluorobenzoyl chloride was used in place of 3-methoxybenzoyl chloride to produce the desired product. NMR analysis showed the product to have a structure consistent with 3,3-di(4-methoxyphenyl-9,9-dimethyl-11-fluoro-3H-9H-15 indeno[3',2':3,4]naphtho[1,2-b]pyran.

COMPARATIVE EXAMPLE 1

20 The procedure of Comparative Example 1 of U.S. Patent 5,645,767 was followed. An NMR spectrum showed the product to have a structure consistent with 2,2-di(4-methoxyphenyl),5-methoxycarbonyl,6-phenyl-[2H]-naphtho[1,2-b]pyran.

25

EXAMPLE 19

Part A

Testing was done with the photochromic compounds described in Examples 1 through 15, 17 and 18 and Comparative Example 1 in the following manner. A quantity of photochromic compound calculated to yield a 1.5×10^{-3} molal solution was added to a flask containing 50 grams of a monomer blend of 4 parts ethoxylated bisphenol A dimethacrylate (BPA 2EO DMA), 1 part poly(ethylene glycol) 600 dimethacrylate, and 0.033 weight percent 2,2'-azobis(2-methyl propionitrile) (AIBN). 35 The photochromic compound was dissolved into the monomer blend

by stirring and gentle heating, if necessary. After a clear solution was obtained, it was poured into a flat sheet mold having the interior dimensions of 2.2 mm x 6 inches (15.24 cm) x 6 inches (15.24 cm). The mold was sealed and placed in a 5 horizontal air flow, programmable oven programmed to increase the temperature from 40°C to 95°C over a 5 hour interval, hold the temperature at 95°C for 3 hours, lower it to 60°C over a 2 hour interval and then hold it at 60°C for 16 hours. After the mold was opened, the polymer sheet was cut using a diamond 10 blade saw into 2 inch (5.1 centimeters) test squares.

Testing of the photochromic properties of Example 16 was done as follows. A portion of the product was incorporated into (diglyme) diethylene glycol dimethyl ether and irradiated with long wave ultraviolet light. The color of 15 the sample changed from clear to brown. After the irradiation was stopped, the color of the sample changed from brown to clear.

Part B

20 The photochromic test squares of Part A were tested for photochromic response rates on an optical bench. Prior to testing on the optical bench, the photochromic test squares were exposed to 365 nanometer ultraviolet light for about 15 minutes to activate the photochromic compounds and then placed 25 into a 76°C oven for about 15 minutes to bleach the photochromic compounds. The test squares were then cooled to room temperature, exposed to fluorescent room lighting for at least 2 hours and then kept covered for at least 2 hours prior to testing on an optical bench maintained at 72°F (22.2°C).
30 The bench was fitted with a 250 watt Xenon arc lamp, a remote controlled shutter, a copper sulfate bath acting as a heat sink for the arc lamp, a Schott WG-320 nm cut-off filter which removes short wavelength radiation; neutral density filter(s) and a sample holder in which the square to be tested was
35 inserted. The power output of the optical bench, i.e., the dosage of light that the sample lens would be exposed to, was

calibrated with a photochromic test square used as a reference standard. This resulted in a power output ranging from 0.15 to 0.20 milliWatts per square centimeter (mW/cm²).

Measurement of the power output was made using a GRASEBY 5 Optronics Model S-371 portable photometer (Serial #21536) with a UV-A detector (Serial #22411) or comparable equipment. The UV -A detector was placed into the sample holder and the light output was measured. Adjustments to the power output were made by increasing or decreasing the lamp wattage or by adding 10 or removing neutral density filters in the light path.

A monitoring, collimated beam of light from a tungsten lamp was passed through the square at a small angle (approximately 30°) normal to the square. After passing through the square, the light from the tungsten lamp was 15 directed to a detector through Spectral Energy Corp. GM-200 monochromator set at the previously determined visible lambda max of the photochromic compound being measured. The output signals from the detector were processed by a radiometer.

Change in optical density (Δ OD) was determined by 20 inserting a test square in the bleached state into the sample holder, adjusting the transmittance scale to 100%, opening the shutter from the Xenon lamp to provide ultraviolet radiation to change the test square from the bleached state to an activated (i.e., darkened) state, measuring the 25 transmittance in the activated state, and calculating the change in optical density according to the formula:

Δ OD= $\log(100/\%Ta)$, where %Ta is the percent transmittance in the activated state and the logarithm is to the base 10.

LABTECH NOTEBOOKpro software was used for all calculations.

30 The optical properties of the photochromic compounds in the test squares are reported in Table 1. The Δ OD/Min, which represents the sensitivity of the photochromic compound's response to UV light, was measured over the first five (5) seconds of UV exposure, then expressed on a per 35 minute basis. The saturation optical density

(ΔOD @ Saturation) was taken under identical conditions as the $\Delta\text{OD}/\text{Min}$, except UV exposure was continued for 15 minutes.

The lambda max (Vis) is the wavelength in the visible spectrum at which the maximum absorption of the 5 activated (colored) form of the photochromic compound in a test square occurs. The lambda max (Vis) wavelengths reported in Table 1 were determined by testing the photochromic test square polymerizates of Part A in a Varian Cary 3 uv-visible spectrophotometer. The bleach rate ($T_{1/2}$) is the time 10 interval in seconds for the absorbance of the activated form of the photochromic compound in the test squares to read one half the highest absorbance at room temperature (72°F , 22.2°C) after removal of the source of activating light.

Each of the compounds of the Examples and the 15 Comparative Example exhibited dual peak absorptions in the visible spectrum (lambda max visible) in distinct color regions. For the highest lambda max visible (Band B), the corresponding optical density ($\Delta\text{OD}/\text{Min}$ and ΔOD at saturation) and bleach rate ($T_{1/2}$) for the desired compounds of the 20 Examples and Comparative Example are tabulated in Table 1.

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TABLE 1

5	Compound <u>Example</u>	Sensitivity <u>ΔOD / MIN</u>	ΔOD @ <u>Saturation</u>	Bleach	
				Rate <u>T 1/2 sec</u>	λ MAX (nm) <u>Vis</u>
	1 (Band A)				416
	1 (Band B)	0.12	0.30	147	516
	2 (Band A)				440
10	2 (Band B)	0.15	0.13	42	534
	3 (Band A)				433
	3 (Band B)	0.16	0.25	88	527
	4 (Band A)				480
	4 (Band B)	0.19	0.28	86	560
15	5 (Band A)				447
	5 (Band B)	0.16	0.16	52	550
	6 (Band A)				435
	6 (Band B)	0.15	0.25	98	546
	7 (Band A)				435
20	7 (Band B)	0.17	0.24	90	547
	8 (Band A)				447
	8 (Band B)	0.16	0.15	47	551
	9 (Band A)				445
	9 (Band B)	0.17	0.15	47	550
25	10 (Band A)				447
	10 (Band B)	0.16	0.11	33	551
	11 (Band A)				434
	11 (Band B)	0.16	0.19	66	548
	12 (Band A)				445
30	12 (Band B)	0.17	0.07	63	541
	13 (Band A)				430
	13 (Band B)	0.13	0.23	153	533
	14 (Band A)				480
	14 (Band B)	0.15	0.34	148	543
35	15 (Band A)				441
	15 (Band B)	0.10	0.05	24	546
	17 (Band A)				430
	17 (Band B)	0.09	0.04	44	536
	18 (Band A)				441
40	18 (Band B)	0.16	0.10	39	535

CE1 (Band A)				422
CE2 (Band B)	0.18	0.22	56	518

The results of Table 1 show that the compounds of Examples 1-15, 17 and 18 demonstrated acceptable photochromic properties, e.g., sensitivity, optical density at saturation and bleach rate. A comparison of the data for the compounds of Examples 2, 5, 8, 9, 10, 12, 15 and 18 which have the same B and B' substituents as Comparative Example 1, to Comparative Example 1 show a higher lambda max for both Bands A and B and a shorter bleach rate for each of the Example compounds. The higher lambda max values for the Example compounds demonstrate a bathochromic shift in the visible spectrum.

The present invention has been described with reference to specific details of particular embodiments thereof. It is not intended that such details be regarded as limitations upon the scope of the invention.